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NEW TERTIARY FORAMINIFERA OF THE GENERA OPERCULINA AND OPERCULINOIDES FROM NORTH AMERICA AND THE WEST INDIES

By Thomas Wayland Vaughan
Scripps Institution of Oceanography, La Jolla, Calif.

and

W. Storrs Cole
Ohio State University, Columbus, Ohio

The specimens on which the species described herein are based have been in the senior author's hands for several years, some of them since 1920. Suites to serve as cotypes had been selected, some photographs for illustrating the species were taken, and, except for *Operculinoides antiguensis*, manuscript names were applied to them, but the descriptions were not written. The final preparation of this paper for publication was done jointly. Seven new species are herein described, as follows:

Operculina tuberculata: Upper Eocene, Tantoyuca formation, Tampico Embayment, Mexico.

Operculinoides advenus: Upper Eocene, equivalent of Tantoyuca formation, Tampico Embayment, Mexico.

Operculinoides vicksburgensis: Oligocene, Byram calcareous marl of Mississippi and Alabama.

Operculinoides semmesi: Oligocene, Mesón formation, Tampico Embayment, Mexico.

Operculinoides antiguensis: Oligocene, Antigua formation, island of Antigua, and probably also Meson formation, Tampico Embayment, Mexico.
Operculinoides forresti: Oligocene, Antigua formation, island of Antigua.
Operculinoides tuxpanicus: Miocene, Tuxpan formation, Tampico Embayment, Mexico.

All types are deposited in the United States National Museum.

The species of *Operculina* and *Operculinoides* here described do not exhaust all the species that should be described. There is at least one other in the Mesón formation of the Tampico Embayment, but material for adequately characterizing it is not now available.

The limits of the variation of the species designated as *Operculinoides semmesi* and *O. antiguensis* are not yet definitely fixed. The notes made under the caption "Remarks" indicate perplexities that require further consideration.

Our thanks are due R. Wright Barker for telling us the stratigraphic horizon of *Operculina tuberculata;* to Ursel S. Armstrong for making some of the preparations; and to W. O. Hazard, of the United States Geological Survey, and E. C. LaFond, of the Scripps Institution of Oceanography, for making the photographs for the plates.

Genus OPERCULINA d'Orbigny

Operculina D'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 281, 1826.

OPERCULINA TUBERCULATA, new species

PLATE 35, FIGURES 1–4

Test small, with a peripheral keel, compressed, coils expanding slowly. Diameter from outer edge of aperture through center, 1.9 mm; diameter at right angles to line through aperture, 1.7 mm; thickness through center, about 0.4 mm.

The number of chambers in the final whorl of a specimen 1.6 mm in diameter is 16; the total number of coils in the same specimen is 3. The chamber walls are very slightly curved for their first half but are strongly and evenly recurved as they approach the periphery. The chamber walls are marked externally by costae and rather coarse granules, as shown in the figures. At the center there is a knob that is larger than the costal granulations, about 0.15 mm in diameter.

Cotypes.—U.S.N.M. no. 495188.

Locality.—Cortez Aguada well no. 2, depths 2,000–3,450 feet, 5.3 km northeast of Chalahuite and 7.2 km south of Aguada in property Aguada-San Diego Valdemar, Cantón of Ozuluama, State of Veracruz, Mexico. Cotypes from depths of 2,625 to 2,800 feet. Specimens received from Dr. W. S. Adkins, of the Aguila Co.

Geologic horizon.—Upper Eocene, Tantoyuca formation.

Remarks.—This species is closely related to *O. mariannensis* Vaughan (1928, p. 158) from the upper Eocene Ocala limestone of Florida, from which it is distinguished by its thicker, more robust form, its larger number of chambers, and its more evolute coiling. There are 11 or 12 chambers in the final coil of *mariannensis*, while slightly smaller specimens of *tuberculata* have 16 or 17. The granulations are coarser and the intercostal areas narrower in typical specimens of *tuberculata*.

Genus OPERCULINOIDES Hanzawa

Operculinoides HANZAWA, Tôhoku Imp. Univ. Sci. Rept., ser. 2 (Geol.), vol. 18, no. 1, p. 18, 1935.

Genoholotype.—*Nummulites willcoxi* Heilprin.

Hanzawa says: "On examining the foregoing listed specimens of *Operculina* [4 species] from America, I found that they all differ from either *Operculina complanata* (senso latu) or *Operculinella venosa* by being involute in the adult stage." A re-examination of *Operculinella venosa* shows that Hanzawa is correct in generically separating the American Tertiary species that have been referred to *Operculinella* Yabe from that genus and in proposing a new generic name for those typified by *Nummulites willcoxi* Heilprin. It seems better to refer such species as those represented by *Nummulites floridensis* Heilprin to another genus, *Assilina*, as Cushman has done; but it must be recognized that the members of the group need additional and more critical study.

OPERCULINOIDES ADVENUS, new species

PLATE 35, FIGURES 5–7

Test of medium size, involute, much compressed, the sides nearly parallel, with a very bluntly rounded periphery. Diameter from outer edge of aperture through center ranges from 1.9 to 3.6 mm; diameter at right angles to line through aperture ranges from 1.8 to 3.4 mm; thickness through center ranges from 0.3 to 0.5 mm. The surface is smooth, not ornamented, in well-preserved specimens; in weathered specimens the sutures appear as slightly raised lines, radiating with gentle curvature from the center to the periphery of the test.

A median section of a specimen 1.9 mm in diameter has 4 complete coils, with 22 chambers in the final coil; the specimen shown in plate 35, figure 6, is 3 mm in diameter and has 28 chambers in the last coil. The variation in the number of chambers in the final volution is from 20 to 28. The initial chamber is circular, about 88μ in diameter. The chambers increase slowly but regularly in height.

In a specimen 2.3 mm in diameter the final chamber has a height of 0.5 mm.

The sutures are thin and radiate nearly straight from the center until near their proximal ends, where they recurve sharply. The curvature is such that the peripheral end of a suture nearly touches the adjacent one.

Cotypes.—U.S.N.M. no. 495189.

Localities.—At the base of the bluff on the Rio Pantepec 2.2 km south, 20° west, from the Buena Vista Hacienda House, Cantón Metlaltoyuca, State of Pueblo (M 71 V); cotypes, Rio Vinazco, right bank, 1.4 km (M 80 V) and 1.35 km (M 81 V) downstream from the road crossing from Buena Vista to Vinazco, Cantón Chicontepec, State of Veracruz. Collected by T. Wayland Vaughan for the Aguila Co.

Geologic horizon.—Upper Eocene, stratigraphic equivalent of the Tantoyuca formation. Associated with *Lepidocyclina tobleri* H. Douvillé, *L. trinitatis* H. Douvillé, and *L. macdonaldi* Cushman.

OPERCULINOIDES VICKSBURGENSIS, new species

PLATE 36

Nummulites sp. CUSHMAN, U. S. Geol. Surv. Prof. Pap. 129–E, pp. 100–101, pl. 24, fig. 4, 1922.

Nummulites sp. VAUGHAN, Geol. Soc. Amer. Bull., vol. 35, p. 787, 1924.

Test rather small, involute, compressed lenticular, outer surface without ornamentation except the traces of flexuous septal markings and a small area of clear shell material in the center from which the septa radiate. The test is nearly circular; the diameter from outer edge of aperture through center ranges from 1.3 to 3.1 mm; diameter at right angles to line through aperture ranges from 1.2 to 3 mm; thickness through center ranges from 0.3 to 0.6 mm. From the central area the test slopes very gradually to the bluntly rounded periphery.

An accidental median section of a specimen (pl. 36, fig. 2) 2.1 mm in diameter shows 3¾ coils, with 18 chambers in the last coil. A thin section of a specimen (pl. 36, fig. 4) 2.5 mm in diameter has 22 chambers in the final volution; another section (pl. 36, fig. 5) has 4 coils and 25 chambers in the last coil. An uncut specimen 2.2 mm in diameter has 22 chambers showing at the surface, while another 2.8 mm in diameter has 26 chambers.

The sutures are moderately thick and radiate from the center with only slight curvature until near the periphery, where they bend backward evenly but sharply. There is a slight but regular increase in height of the chambers. The initial chamber is circular, about 60μ in diameter.

Plate 36, figure 4a, illustrates a decalcified Canada balsam impregnation of the canals in the marginal cord and an interseptal canal, magnified 210 times.

Cotypes.—U.S.N.M. no. 495190.

Localities.—Cotypes, road below National Cemetery, Vicksburg, Miss.; Robinson Quarry, sec. 19, T. 5 N., R. 9 E., 3 miles east of Brandon, Miss.; and one-fourth mile west of Floral Church, creek beneath bridge, S½ sec. 27, T. 3 N., R. 14 E., Covington County, Ala. All collected by Dr. C. Wythe Cooke.

Geologic horizon.—Byram calcareous marl, topmost formation of the Oligocene Vicksburg group at and near Vicksburg, Miss.

OPERCULINOIDES SEMMESI, new species

PLATE 37, FIGURES 10–13, probably FIGURE 14; PLATE 38, FIGURES 1, 2, probably FIGURES 5, 6

Test small, completely involute, lenticular, with a slightly extended thinner edge in fully adult perfect specimens. Diameter, 1.75–2.8 mm; thickness, 0.55–0.65 mm. In many specimens there is a small central knob.

The sutures on perfect specimens are somewhat raised and are curved as shown by the upper left specimen in plate 37, figure 10. The number of chambers in the specimen shown on plate 37, figure 11, is 18, and there are about 3½ coils; the number in the specimen shown on plate 38, figure 2, is 19. Other specimens that appear to belong to the same species have fewer chambers, as few as 14 (pl. 37, fig. 14) or 15 (pl. 38, fig. 5). The proximal part of the chamber walls is nearly straight, while the distal part curves backward.

Cotypes.—U.S.N.M. no. 495191.

Localities.—The cotypes are from the arroyo in the center of Mesón Village, Cantón of Tuxpan, State of Veracruz, Mexico. Slightly worn but typical specimens were collected by T. Wayland Vaughan (M 36 V) at Azteca Incline, Zacamixtle, Cantón of Tuxpan, Veracruz. Other localities are on the east side of Rio Buena Vista, opposite La Ceiba crossing, along the slope, about 50 feet above the base of the bluff on the river (M 55 V and M 56 V). Specimens that appear to belong to this species were found at many localities where the Mesón formation is exposed, but to be sure of the identification thin sections are necessary. All the collections were made by geologists connected with the Aguila Co.

Geologic horizon.—Oligocene Mesón formation.

Remarks.—*O. semmesi* is a small, robustly lenticular species with a peripheral flange in perfect adult specimens. Apparently the chambers in the last coil range from 14 to 19, but larger suites of

good specimens may result in the separation of those specimens with 14 or 15 chambers from those with 18 or 19. At locality M 55 V, specimens with more chambers, 24 (pl. 38, fig. 3), and more robust tests (pl. 38, fig. 4) were collected. The similarity of these specimens to *O. semmesi* is obvious. They may represent a variant or they may belong to a closely related but different species. There may be several species of these small specimens of *Operculinoides* in the Mesón formation.

OPERCULINOIDES ANTIGUENSIS, new species

PLATE 38, FIGURES 7–10

Test of medium size, completely involute, lenticular, symmetrical or asymmetrical with reference to the median plane, edges acute. Diameter, 2.5–3.7 mm; thickness of a specimen 2.5 mm in diameter, 1 mm; of a specimen 3.25 mm in diameter, about 1 mm.

Sutures are of clear shell material, smooth and usually flush with the surface, radiating as gently curved lines from the center of the test to the periphery. Some of the sutures do not extend to the center but may converge in groups of three or four, with only one of the group extending to the center. In most specimens there is a small irregular area of clear shell material at the center of the test, and in a few specimens there is a slight boss of clear shell material.

The variation in the number of chambers in the final volution is from 29 in a specimen 3 mm in diameter to 33 in one about 3.5 mm in diameter. The chamber walls in median sections are somewhat sigmoid, the proximal end tending to curve forward slightly, the outer half strongly recurved.

Cotypes.—U.S.N.M. no. 495192.

Localities.—Cotypes, east side of Folly Hill, Nonsuch Bay, Antigua, collected by W. R. Forrest. The species is also found at numerous other localities in Antigua, one being in the lowest tilted beds, on the beach, at Lynch Point. What appears to be the same species was collected by T. Wayland Vaughan in the Mesón formation at locality M 18 V, Hacienda Santa Fé, Topila, near Tampico, Mexico. A specimen in a rock section from this locality is 2.33 mm in diameter and has between 26 and 28 chambers in the last coil.

Geologic horizon.—Oligocene Antigua formation in Antigua, British West Indies; and apparently also in the Oligocene Mesón formation of the Tampico Embayment, Mexico.

Remarks.—For some time the specimens to which the name *Operculinoides antiguensis* is here applied were placed in *O. semmesi*, but further study of the material has led to the conclusion

that two species should be recognized. Of the two, *antiguensis* is the larger, it has more numerous chambers, and in a median section the chamber walls tend to be sigmoid in plan.

OPERCULINOIDES FORRESTI, new species

PLATE 37, FIGURES 1–3

Test small, thin, compressed, with the sides nearly parallel; average specimens have a diameter from outer edge of aperture through center of test of about 2.5 mm; diameter at right angles to line through aperture, about 2.3 mm; the largest specimen observed had a diameter of about 3 mm. The thickness of an average specimen is about 0.3 mm. The surface is without ornamentation, except for the slightly raised recurved septa, which are more pronounced toward the periphery of the test.

A specimen with a diameter of 1.9 mm has 3 whorls, with 16 chambers in the final coil; another 2.6 mm in diameter has 4 whorls, with 21 chambers in the final whorl. The maximum number of chambers observed in the final volution was 24.

The chamber walls are but slightly curved for most of their length, radiating outward at 90° from the inner wall. As they approach the periphery they are sharply and strongly recurved, so that the end of one septum nearly touches the point of strong curvature of the adjacent septum.

In most specimens there is a very gradual increase in height as the chambers are added.

Cotypes.—U.S.N.M. no. 495193.

Localities.—Cotypes, tilted beds, east of Lynch's, Antigua; cliff, east of Gaynor's, Antigua, and many other Antiguan localities; collected by W. R. Forrest.

Geologic horizon.—Middle Oligocene, Antigua formation.

Remarks.—This species resembles closely *O. dia* Cole and Ponton (1930, p. 37) described from the Marianna limestone. They are similar in possessing rather fragile, compressed tests. Detailed comparison of *forresti* with topotype specimens of *dia* at once indicates that there are important differences. *O. forresti* is usually larger, has fewer chambers in the final volution, has a different type of curvature of the chamber walls and raised septal lines. Cole and Ponton's figures and topotype specimens of *dia* show that in that species the proximal parts of the chamber walls are gently curved, whereas in their distal parts the curvature is strong. The sutures of *O. forresti* are nearly straight from the center for about three-fourths of their length, but near the periphery they are strongly and sharply recurved.

O. dia is associated with *Lepidocyclina mantelli* (Morton) and is a characteristic species of the lower Oligocene, whereas *O. forresti* is associated with species of *Lepidocyclina* of middle Oligocene age.

OPERCULINOIDES TUXPANICUS, new species

PLATE 37, FIGURES 4–9

Test small, fragile, compressed, completely involute, without ornamentation except for traces of the septal lines. Diameter from outer edge of aperture through center ranges from 1.7 to 3.2 mm; diameter at right angles to apertural plane ranges from 1.5 to 3 mm; thickness through center ranges from 0.3 to 0.5 mm. The test is thickest through the center and slopes gradually to the rather sharply rounded periphery.

A section of a specimen about 1.6 mm in diameter has 3 coils, with 19 chambers in the final volution. Another specimen about 2.5 mm in diameter has 3½ coils, with 20 chambers in the final whorl.

The chamber walls are gently recurved except near the periphery, where they are sharply recurved. Some of the chamber walls vary from this pattern, as shown in the figures. These exhibit a gradual and regular recurvature throughout their length. The incorporation of two types of curvature in the same test gives the chambers an irregular appearance and shape.

Cotypes.—U.S.N.M. no. 495194.

Locality.—Roundtop, just southeast of the Plaza, City of Tuxpan, Veracruz, Mexico (M 76 S); collected by D. R. Semmes.

Geologic horizon.—Tuxpan formation of Miocene age.

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1928. New species of *Operculina* and *Discocyclina* from the Ocala limestone. 19th Ann. Rep. Florida State Geol. Surv., 1926–27, pp. 156–164, 2 pls.

EXPLANATION OF PLATES

Plate 35

1–4. *Operculina tuberculata*, new species, cotypes: 1, View of outside of three specimens, × 12.5; 2, median section, × 15; 3, transverse section, × 20; 3a, part of section represented by fig. 3, × 107; 4, transverse section, × 20.

All from Cortez Aguada well no. 2. Fig. 1, depth 2,750–2,800 feet; fig. 2, 2,675–2,725 feet; figs. 3 and 4, 2,625–2,650 feet.

5–7. *Operculinoides advenus*, new species, cotypes: 5, View of outside of two specimens, × 13; 6, median section, × 20; 7, transverse section, × 20. From M 80 V and M 81 V, Rio Vinazco, 1.35–1.4 km downstream from crossing of road from Buena Vista to Vinazco.

Plate 36

Operculinoides vicksburgensis, new species

1. View of outside of four specimens, × 10.
2. Natural section in median plane, × 20.
3. Section in median plane, × 20.
4. Section in median plane impregnated with Canada balsam and decalcified, × 20.

4a. Part of outer wall and chamber wall of specimen represented by fig. 4, showing canals filled with balsam, × 210.

5. Section in median plane, × 20.
6. Transverse section, × 20.

Figs. 1–4a and 6, cotypes, from Byram calcareous marl, National Cemetery, Vicksburg, Miss. Fig. 5, from one-fourth mile west of Floral Church, Covington County, Ala.

Plate 37

1–3. *Operculinoides forresti*, new species, cotypes: 1, Outside of specimen, × 10; 2, median section, × 20; 3, transverse section, × 20.

All from tilted beds, east of Lynch's, Antigua.

4–9. *Operculinoides tuxpanicus*, new species, cotypes: 4, 5, Outside of two specimens, × 10; 6, 7, sections in median planes of two specimens, × 15; 8, 9, transverse sections of two specimens, × 20.

All from M 76 S, Roundtop, southeast of the Plaza, City of Tuxpan, Veracruz, Mexico.

10–13. *Operculinoides semmesi*, new species, cotypes: 10, View of outside of four specimens, × 12.5; 11, section in median plane, × 20; 12, 13, transverse sections of two specimens, × 20.

All from village of Mesón, Cantón of Tuxpan, Veracruz, Mexico.

14. Apparently *Operculinoides semmesi*, but with slightly fewer chambers in a whorl.

From Mesón Village.

PLATE 38

1, 2. *Operculinoides semmesi*, new species: 1, Outside of specimen, × 10; 2, median section, × 15.

Both from M 36 V, Azteca Incline, Cantón of Tuxpan, Veracruz, Mexico.

3, 4. *Operculinoides* sp. cf. *O. semmesi:* 3, Median section, × 20; 4, transverse section, × 20.

Both from M 55 V, 50 feet above base of bluff, up slope leading from La Ceiba crossing over Rio Buena Vista, Cantón of Tuxpan, Veracruz, Mexico. Note that in fig. 3 there are more chambers than in pl. 37, fig. 11, and in pl. 38, fig. 2, and that fig. 4 is thicker than specimen shown on pl. 37, figs. 12 and 13.

5, 6. Apparently *Operculinoides semmesi:* 5, Median section, × 20; 6, transverse section, × 20.

Both from M 56 V, near La Ceiba crossing over Rio Buena Vista, same horizon as M 55 V.

7–10. *Operculinoides antiguensis*, new species, cotypes: 7, View of outside of two specimens, × 12.5; 8, median section, × 20; 9, 10, vertical sections of two specimens, × 20.

All from east side of Folly Hill, Nonsuch Bay, Antigua, British West Indies.

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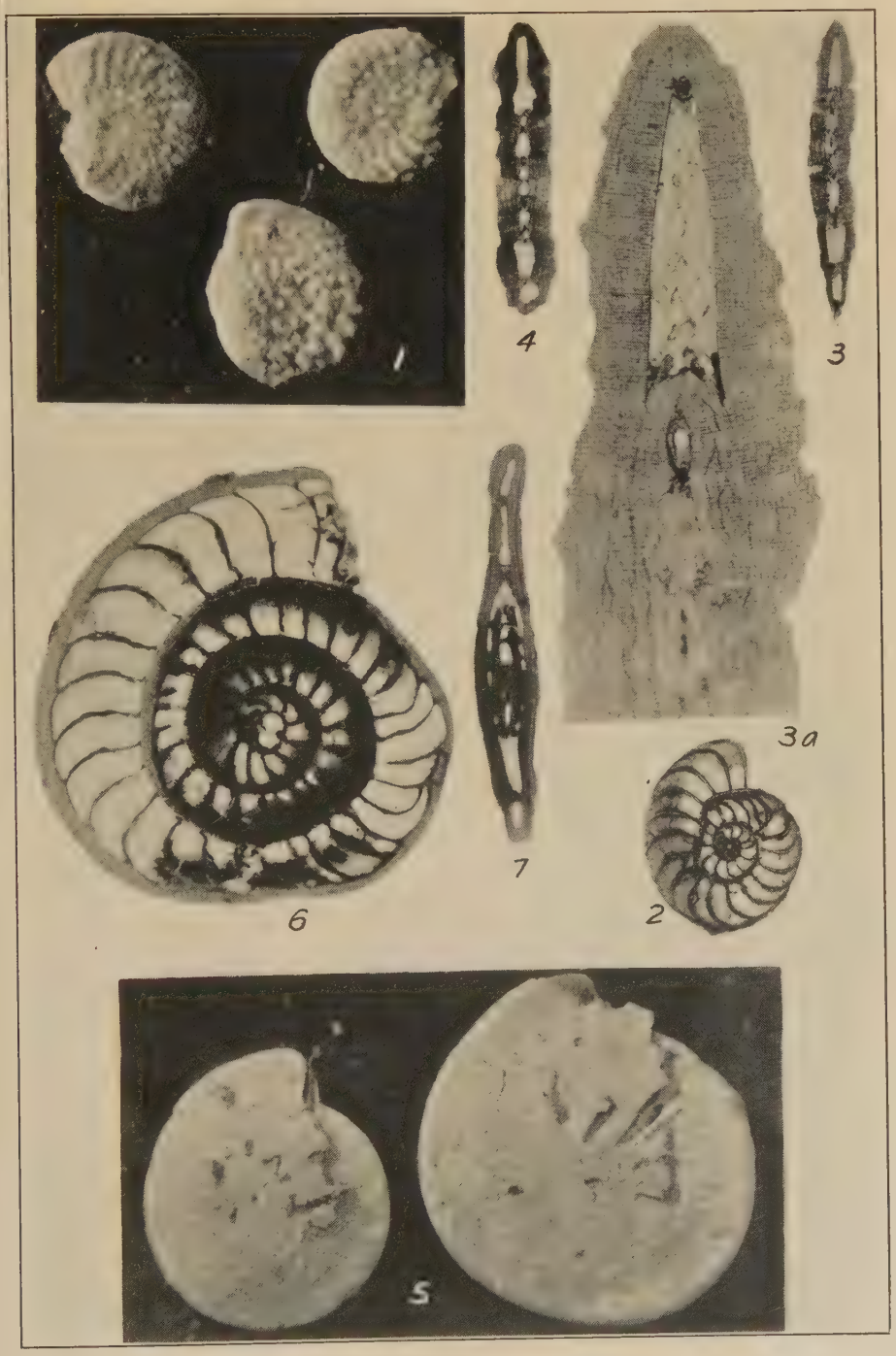
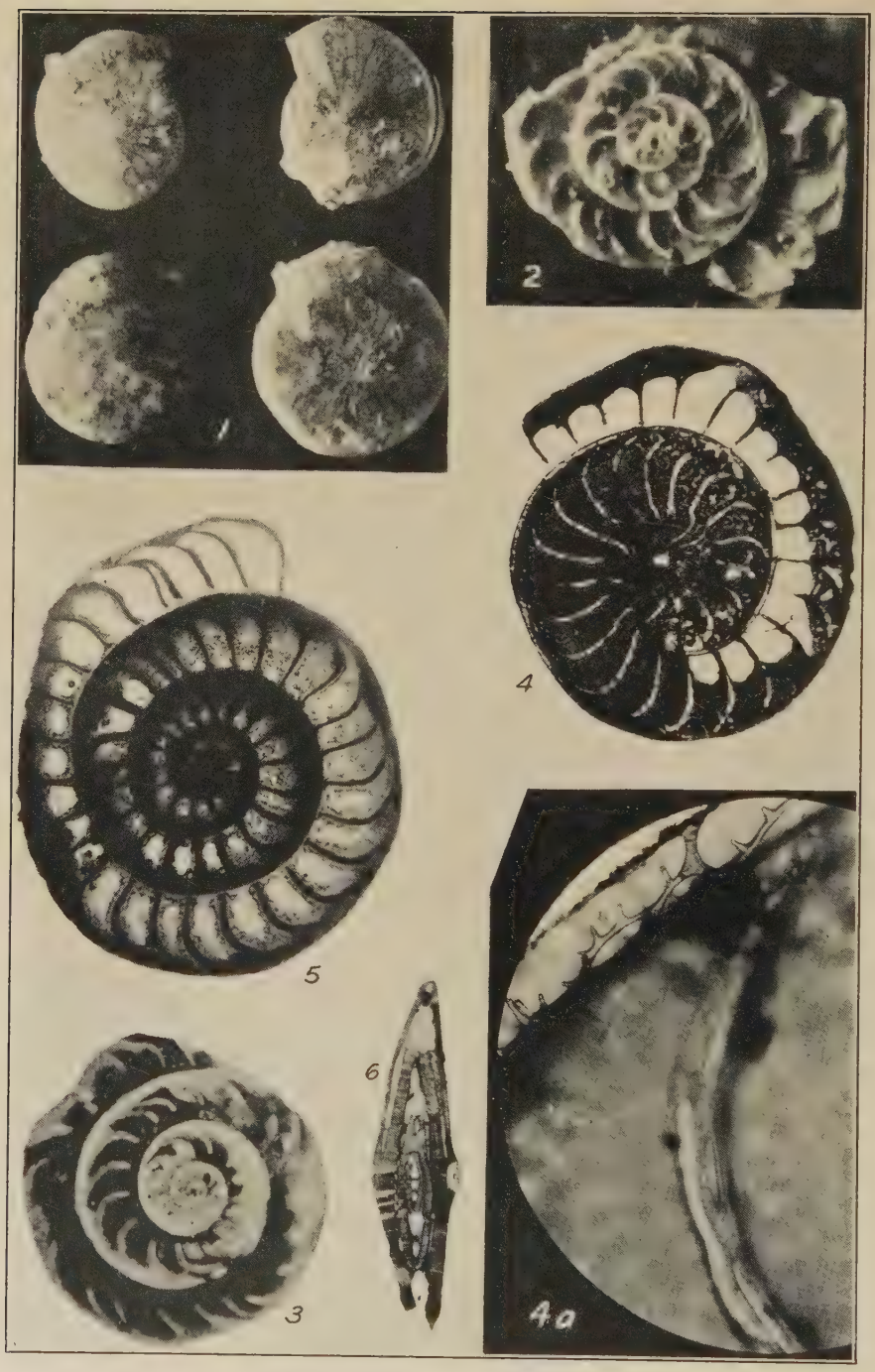


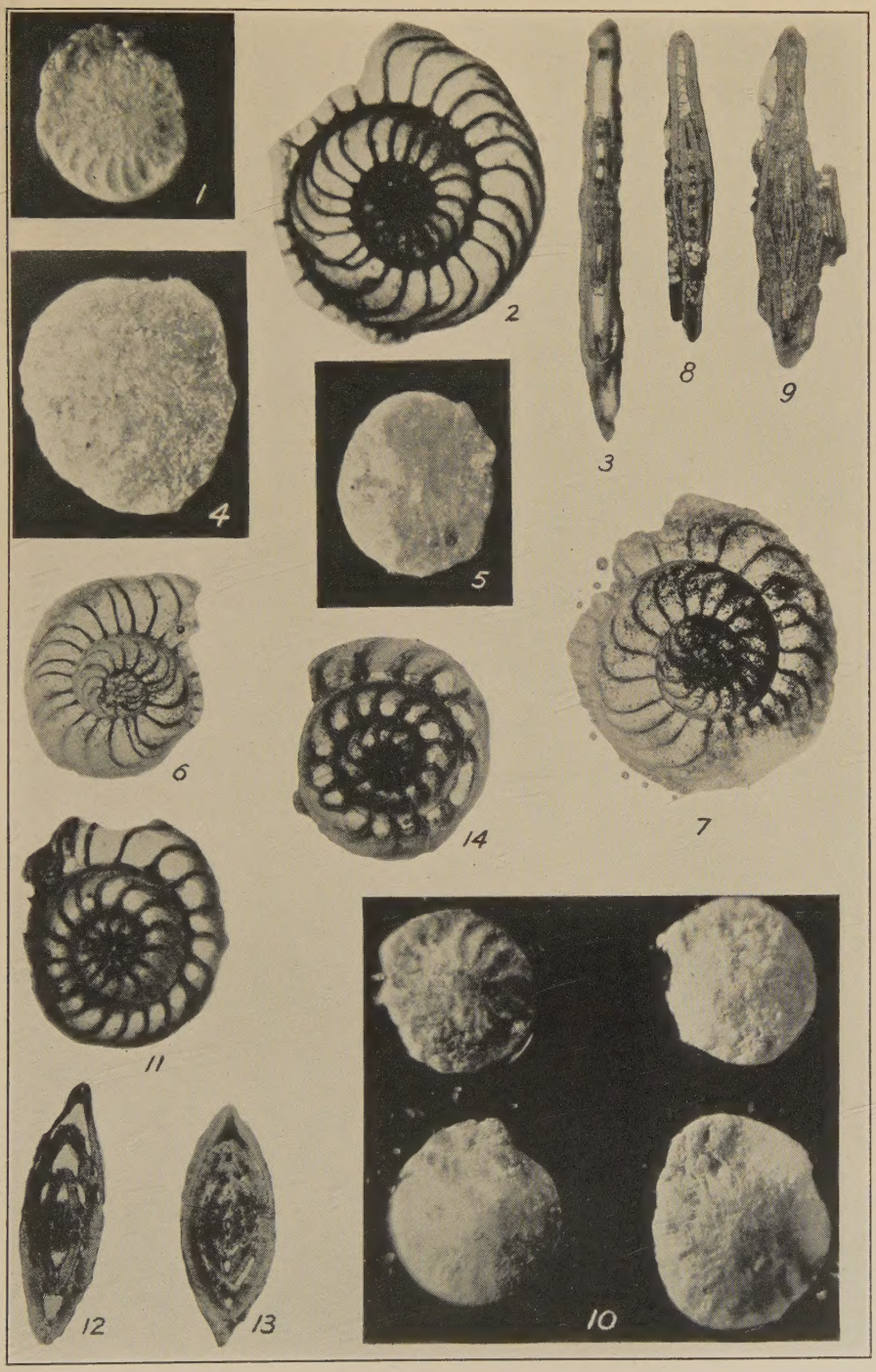
NEW TERTIARY FORAMINIFERA.

(FOR EXPLANATION OF PLATE, SEE PAGE 495.)



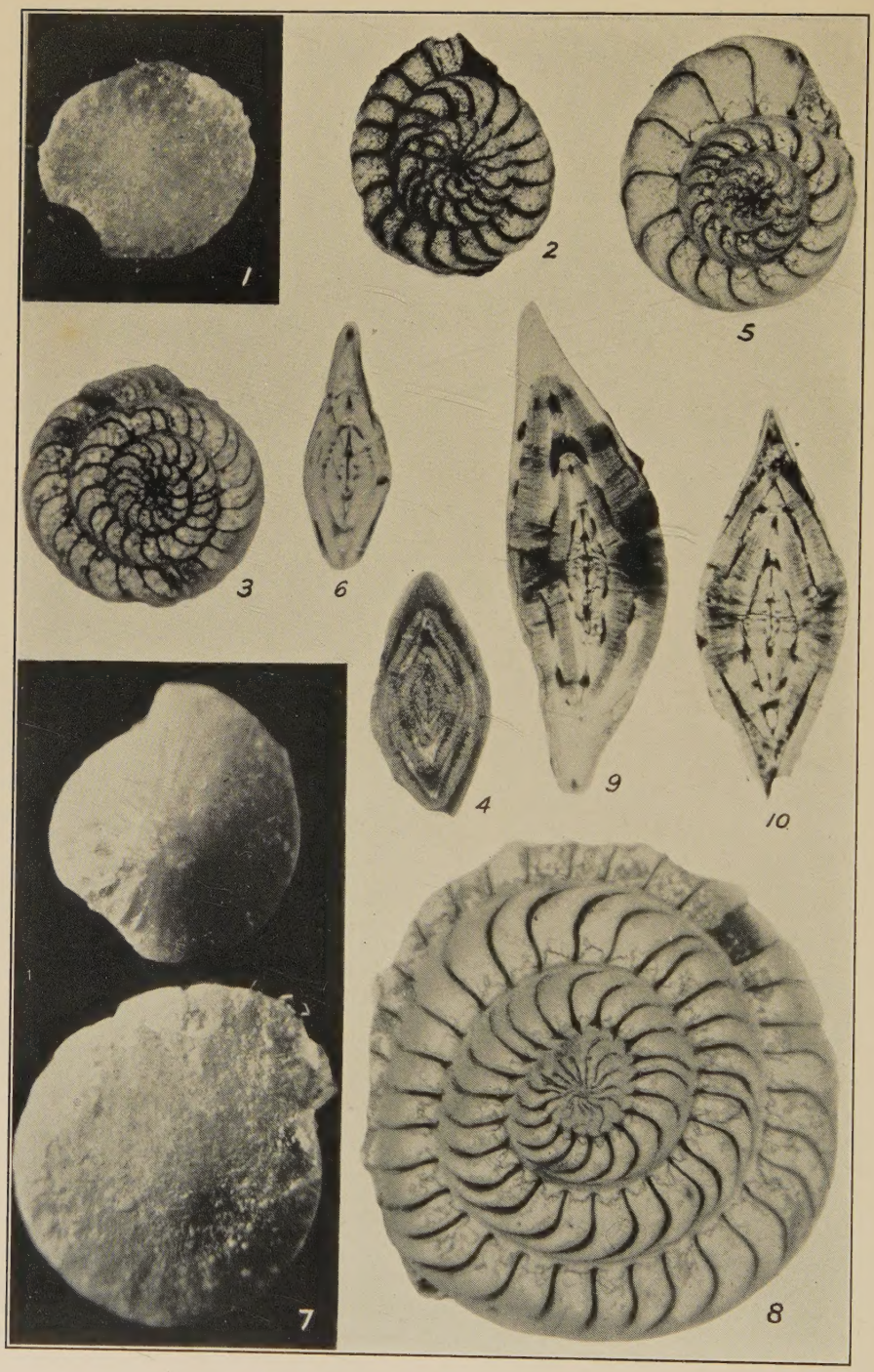
NEW TERTIARY FORAMINIFERA.

(FOR EXPLANATION OF PLATE, SEE PAGE 495.)



NEW TERTIARY FORAMINIFERA.

(FOR EXPLANATION OF PLATE, SEE PAGE 495.)



NEW TERTIARY FORAMINIFERA.

(FOR EXPLANATION OF PLATE, SEE PAGE 496.)